Water Shortage and Food Production in China: Issues, Potential and Solutions

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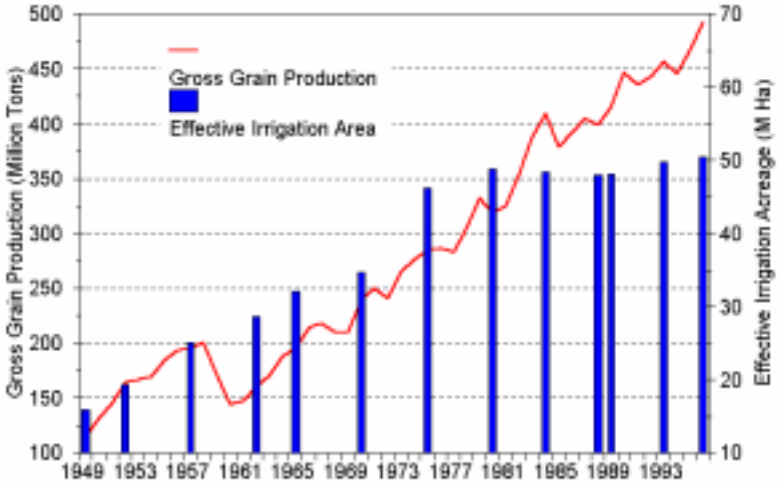
Abstract:: Shortage, incapable increment, and uneven distribution of water resources have developed to be a major resource limitation to China's agriculture, but low use ratio and use efficiency of water resources in agriculture have technically limited the growth of food production. Therefore, under the condition of water shortage, water conservation agriculture is encouraged to aim at improving crop water use ratio and efficiency in the field. Simultaneously, the accelerating development of scientific research, transferring and extension is emphasized in order to improve water use efficiency of food production, and be a prior strategy to China's food security.

1. Introduction - Water Shortage of China's Agriculture

1.1 Shortage of Gross Water to Agriculture

China is one of the countries that suffer from severe water shortage. It is estimated that the mainland annual precipitation accounts to 6188 billion cubic meters (BCM), in which 3387 BCM of water is consumed by continental biological cycle, and 2810 BCM is transformed to water resources (runoff, surface and ground water). Nowadays, the water resource per capita accounts to 2300 m^3 that is 25% of worldwide average. The water resource per acreage of cultivated land and irrigated farmland are 80% and 19% of world average respectively. Water shortage and thus the increment of irrigation cost have yielded a growth hesitation of irrigation. Since 1975, the effective irrigation acreage of the country had been preserved in 48.0-48.7 million hectares with a steady irrigated water quantity of 350-380 BCM. In addition, 6.67 million hectares of the effective irrigation acreage have difficulty to irrigate.



Comparison of Gross Grain Production and Effective Irrigation Area (China, 1949-1996)

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1.2 Uneven Spatial and Temporal Distribution of Water Resource

The cultivated land in the north of Youngtze accounts to 65% of the gross but the water resource is only 20% of the whole. Therefore the water shortage in the north is the major limitation to the local agricultural production. On the other hand, monsoon climate dominates a temporal uneven precipitation that 60-70% of the rainfall occurs during summer from June to September, even 80% in North of China. Such distribution pattern of water resource does not only induce the difficulty of water utilization, but also lead to severe drought and flood.

1.3 Incapable Supply Increment and Aggravating Deficit of Water in Agriculture

On one hand, supply of agricultural products that can meet the needs of population increment requires water increment to agriculture. On the other hand, water portioned to agriculture decreases annually. It is evidence that the water supply to agriculture may be impossible to increase. During 1949–1975, irrigated water amount and irrigated acreage had expended annually. Since 1978, the annual gross grain production has been achieved from 305 million tons to 492 million tons. Meanwhile, the portion of agricultural gross against national gross of annual water use has descend from 88% to 72% at the same period, which the agricultural water gross has maintained about 390-400 BCM. The irrigated water has amounted about 350-380 BCM as the same period, that the portion has changed from 80% to 65% (see table 1). Refer to the estimation, till 2030 when Chinese population will reach to 1.6 billion, national gross of water use will achieve to 800BCM, but the agricultural portion will be reduced to 52%. Therefore, agricultural gross especially irrigation gross of water supply have no significance to increase while gross grain production should be achieved by 640 million tons. Such condition will consequently yield an increment of water deficit.

Table 1. Change of Water Use in Agriculture of China

year	Agricultural Gross	Irrigation Gross	Portion of National Gross %	
	10^8 m^3	10^8 m^3	Agriculture	Irrigation
1949	1,001	956	96.3	92.0
1957	1,938	1,853	94.1	90.0
1965	2,545	2,350	92.0	85.0
1970	3,000	(2,700)	(90.0)	(81.0)
1980	3,912	3,574	87.8	80.5
1988	--	3,874	--	--
1993	4,111	3,440	79.5	66.5
1997	3,960	3,598	72.0	65.4

Data: China Annals of Water Conservancy, Ministry of Water Resource, ()=estimated.

The foregoing fact, that gross grain production has achieved big increment while irrigation water use and acreage hesitated, show us that food production will no longer depend upon resource

consumption after the exploitation of available water resources. Water deficit and low comparable benefit in agriculture will however shift food production to efficient use of limiting water resources.

2. Anxious Situation of Water Use in Food Production of China

The situation of water use in food production in China should be concluded by comprehensive contradictions among deficit increment, low use ratio and efficiency, over consumption and waste, quality depressing, and can be represented as follow:

2.1 Low Rainfall Transformation and Utilization while Over Consumption Exists

Concentrated rainfall, large runoff discharge as well as effective dams and storage conduct a low available resource coefficient of precipitation of 45%. A 400BCM of annual water use in agriculture is only 6.5% and 14.2% of mainland rainfall and gross water resource respectively but **half** of ground water. In well-irrigation region, especially in North of China, change of cultivation system requires more water than the available rainfall, and yields a water deficit in agricultural production. Such gap between need and supply is filled out by over exploitation of ground water. Consequently, water table depresses annually, and some rivers dry out. On the other hand, China has 80 million hectares of dryland farming area where 70% of it locates in the region with annual rainfall of 250-600mm and characterized as semi-arid and dry sub-humid region. In the region, only is **half** of the field rainfall used by food production. These two **halfs** indicate the fact that there exist less effective use of natural rainfall while over consumption of groundwater in agriculture. Such condition also shows the philosophy in water use of emphasizing the engineering and ignoring agronomic solution, and at the end restricting the development of water conservation in agriculture.

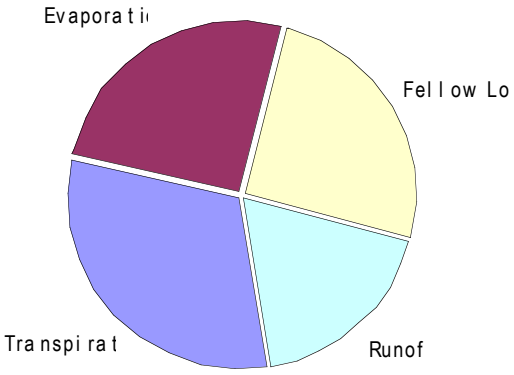

Fig 2 Rainfall Use of Dryland Farming

2.2 Water Shortage and Irrigation Waste Exist Simultaneously

In 1997, the irrigation acreage led to 50 million hectares that accounted to 40% of irrigation coefficient of the cultivated land. Meanwhile, the amount of irrigation water came to 360 BCM that is 65% of the national gross of water use. Such selection had to put forward in order to ensure the food security although the water is deficit. But in deed, the irrigation acreage is composed by ditch pattern that water loss due to carrier infiltration is estimated up to 50%. On the other hand, the

extensive irrigation means such as flood irrigation yield higher field evapotranspiration. Therefore, actual irrigation water is only used by 1/3. Furthermore, extensive irrigation had difficulty to control irrigation quantitatively. Thus, a 7500 CM of water per hectare might occur and consequently conduct an excessive water supply refer to water requirement when it combined with rainfall. So that severe waste of water limited the benefit of irrigated farming.

2.3 Water Use Efficiency Stands Low

Currently, the water use efficiency (WUE) of irrigation water and rainfed field value as 0.87 kg m^{-3} and 0.67 kg m^{-3} respectively, which show the low WUE in agricultural procedure. Meanwhile, the exploitation of groundwater raises as 30% of the available capacity that has contributed 1/5 to national gross of water use, or 1/2 to agricultural water consumption. Such exploiting degree of groundwater has been same as that of the USA, but China hasn't achieved similar agro-economic growth to USA. It is evident that WUE in Chinese food production is low. In fact, it indicates also that there exists valuable potential of food production under the water shortage.

2.4 Pollution Aggravating the Water Shortage and Deficit

Water pollution in China develops following the growth of population, economy, etc. due to wastes emission, as well as agricultural residues such as pesticide, chemicals. Pollution combining the water shortage limits the capability of water self-purifying in the hydrological cycle. Water pollution, in view of biotic production, is a quality shortage that restrains the food quality.

2.5 Under-awareness on Science and Technology of Water Conservation

Historically, Water to agriculture is favor of the god. But socioeconomic growth changes the rule and water shortage knots human beings. In China, awareness of water shortage is quite weak in rural region, and science and technology of water conservation are transferred fragemented. In addition, the investment of central government to water conservation in the past decades had been increased, but the turns in technique and benefit are far from the desired prospect. The external conclusion of such result looks like the contradiction between passive technical need of the farmer and scientists' own wishful thinking, but its kernel is owing to the deviation between the value and price of the water resource in agriculture. Therefore, policy, awareness, technical publicity, and others of water conservation involve in the final solution.

3. The Potential of Agricultural Solution to Water Shortage

3.1 Improving Water Use Efficiency is the Ultimate Solution to Water Shortage

Shortage of water makes China's agriculture search the growing outlet between two

difficulties. On the one hand, water shortage requires agriculture limit water consumption as possible as it can. On the other hand, huge press of population, land, industrialization and urbanization requires agriculture yield higher food production that should supply agriculture sufficient water. In deed, water shortage of food production obscures the waste of limited water resource. Thus the key solution is to improve water use ratio and efficiency.

The agricultural practices indicate that low water use efficiency intensifies water shortage to agriculture, and further induces the low comparable profit against other industries. Therefore, solution to develop food production and ensure food security is to understand the kernel throughout the exterior of water shortage, i.e. agricultural output per cubic meter that is used in the field.

3.2 Two Potentials Comparison

Grain production is the most important part of food production, as well as most sensitive to water shortage. Today, China's grain gross production amounts to 490 million tons, and the weight mean WUE according to WUE and acreage of irrigated and rainfed farmland values as 0.75 kg m^{-3}. Thus, each ton of grain production consumes 1333 m^3 of water. Then the gross water consumption of grain production is at least 653 BCM. Assuming that the ditch carrier coefficient of water is high to 0.5, the effective irrigation water to grain production is only 178 BCM out of 355 BCM. The rest 476 BCM consumed by grain production comes from precipitation. If you compare the values between proportion of rainfall consumption by grain production against mainland biotic cycle and proportion of cultivated land acreage against mainland acreage, you may find that these two proportions are almost the same. In another words, well-managed agro-ecosystem has same rainfall use capacity as other natural ecosystem. It is obvious that China contains huge potential to develop her water conservation agriculture behind the water shortage.

The engineering measures can improve agricultural capability to use precipitation and water resource. Supposed that water use ratio is improved 10% by adopting engineering measures and WUE maintains current level, producing 640 million tons of gross grain will require 853 BCM of gross water supply. If there is no significant increment of irrigation water (in fact that it is true), rainfall and irrigated water can only contribute 550 BCM and 213 BCM to the gross water requirement. There still exist a 90 BCM of water shortage. It is evident that both huge investment and actual capability of water increment limit such solution.

Nowadays in China, WUE of grain production is not high enough even compare to developing countries. Countries that water conservation production is well managed have achieved less water consumption per ton of grain production that below 1000 m^3. If we take the genetic potential, for example, each tons of maize, wheat and rice production can only consume 500-600, 500-700 and 900 cubic meters of water respectively. Admittedly, gaps between actual and potential WUE exist in our grain production. In addition, fitting such gaps is the optimal solution for developing country like China. Practices of rainfed and irrigation farming in China have approved the fact that WUE of grain production can reach to 1.0kg m^{-3} economically throughout the adoption

of agronomic and biological measures. It is also important that such solution can avoid tremendous engineering invests and integrate the water conservation techniques into normal husbandry activities. Assuming the WUE of grain production in China is improved as 1.0kgm^{-3}, the production of 640 million tons of grain, that can ensure food security for 1.6 billion population by 2030, requires the same water supply of 640 BCM, i.e. the growth of grain production does not increase water consumption. It is a obvious potential and profit.

4. Strategic and Technical Opportunities to Improve WUE of Food Production

Under the cruel condition of water shortage, the essential task to put the food production forward is to efficiently use precipitation and irrigation water throughout soil moisture adjustment and control in limiting cultivated land, to optimize integrated water use efficiency of crops, and to continuously improve the yield of each cubic meter of water.

4.1 Improve Rainwater Use Efficiency of Grain Production

The key issues of improving rainwater use efficiency is to foster and enhance the water capacity of soil reservoir, as well as eliminate soil and water erosion. Opportunities can act at different scale.

- Rainwater Harvesting. Planing the runoff control and storage of non-cultivated land according to the rate of cultivated and non-cultivated land as well as valley features. Construction of small rainwater storage that harvests the non-farmland rainfall can adjust spatial and temporal distribution of rainwater, and increase the available water that supply to farmland.
- Field Rainwater Catchment. Develop field rainwater catchment in dryland farming region in northern China and rainfed farming hilly region in southern of China. Ridged cultivation, contour tillage, terrace are useful to harvest rainwater locally so that rainwater can redistribute in flat field or runoff can effectively be reduced and stored in the slope field. These means can also function as improving field rainwater infiltration and erosion control.
- Root-zone Rainwater Concentration. Colophon and fiber have higher water absorb and retain capability. Design the formula and preparation that contains colophon or fiber and integrated with nutration and apply into root zone can concentrate limited soil water and maintain it adjacent to crop root system. It can function when seedling or small amount of rainwater available in dry season.
- Soil Reservoir Cultivation and Enhancement. Protected tillage such as mini- or non-tillage, deep pine can effectively reduce the erosion. Mulching of plastic and straw can restrain the evaporation. Organic manure helps to improve soil porosity and composition, and therefore function to raise rainwater infiltration, enlarge soil water capacity. Means ahead concentrate on maximizing the rainwater storage into field and minimizing the water loss from field so that can sufficiently use rainwater.

4.2 Integrated Technologies to Improve Crop WUE

The key of improving crop WUE is determined by either precisely feeding crop with water and nutrition according to its requirement, or taming crop to be tolerant to inadequate growth environment. Under the condition of water shortage, adjustment and control of field moisture and nutrition can elaborate their positive interaction. Biological breeding and inadequate taming help the crop tolerant to environmental adversity. Modern tillage and fertilization technologies accelerating biomass accumulation. Thus the crop WUE can be improved by the measures ahead.

4.3 Develop Modern Managing System Irrigation Techniques for Water Conservation

Water allocation, regional soil moisture forecast, crop real-time-irrigation predict, and insufficient or deficit irrigation, infiltration and evaporation prevention of water carrier are the majority of modern managing system for water conservation. Furthermore, reducing the water loss during irrigation procedure function as improving available WUE by using modern irrigation techniques such sprinkler, dripline, mini-sprinkler, seeper, etc..

4.4 Political System Building to Improving WUE of Food Production

Political system building is the essential to promote the transferring and extension of modern techniques for water conservation in food production. Such task involves:

- Formulation of cost assessment system and price policy of water resource aimed at sustainable development of food production.
- Perfection of developing planning to water conservation agriculture.
- Establishing new industry that supports water conservation in agriculture.
- Establishing standardized channel for invests and finance
- Establishing farmer-participated water management organization
- Strengthen technical training and extension of water conserved production

4.5 Strengthen Scientific Research and International Cooperation to Efficiently Use Water in Food Production

The urgent scientific research fields nowadays to China's growth of water conservation in food production are:

- Water scarcity and food security
- Interaction among crop, nutrition and water
- Integration of water conservation techniques between engineering and agronomic aspects that focus on field
- Efficient water use and environmental protection
- Equipment, material, and manufactory of water conserved irrigation
- Expert Support Decision Making System for management of water conservation

In China that such an agricultural country with huge population and water scarcity, improving the water use efficiency is meant the technical and capital substitution of deficit water resources, i.e. develop water conservation agriculture by technologies and invests. China is a developing country. The development of water conservation in food production requires not only the capacity building ourselves but international cooperation so as to promote the growth of water conservation industry to ensure the food security of China and the world in 21st century.